Small system flow measurements from the PHENIX experiment at RHIC

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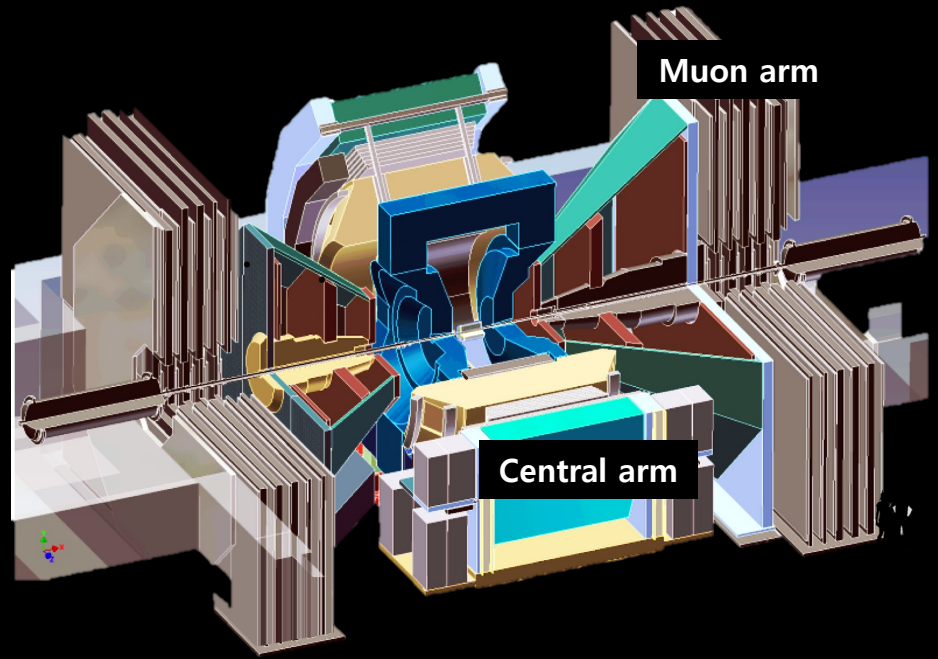
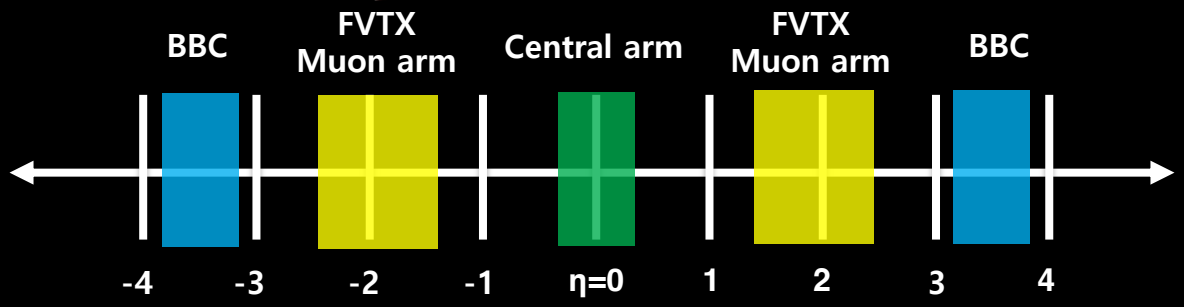
RHIC&AGS AUM 2024

PHENIX

PUSAN NATIONAL UNIV.
NPL
NUCLEAR PHYSICS LAB





Large Rapidity Coverage

PHENIX experiment

Initial geometry

p+Au

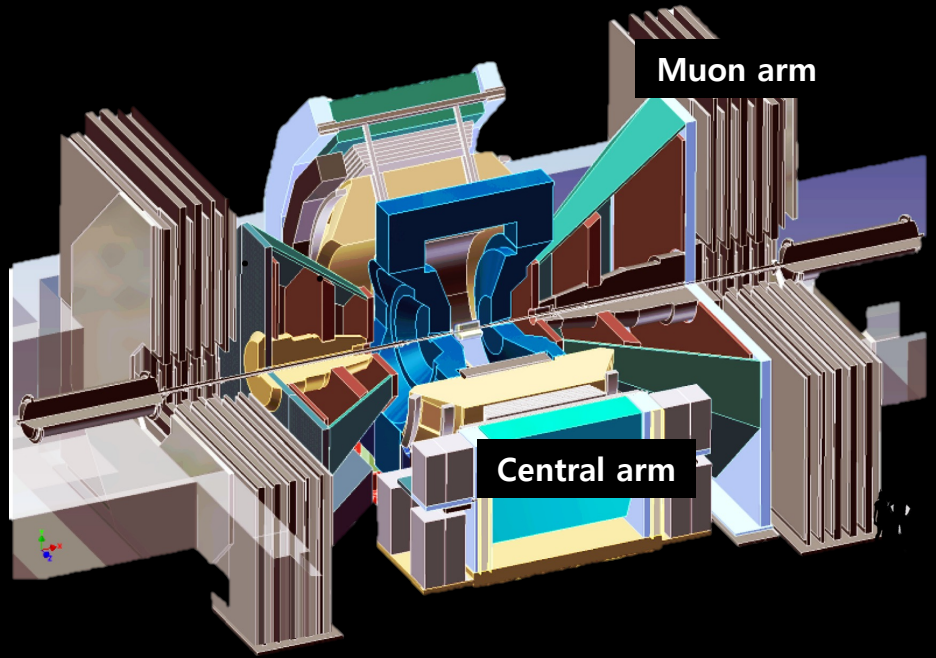
d+Au

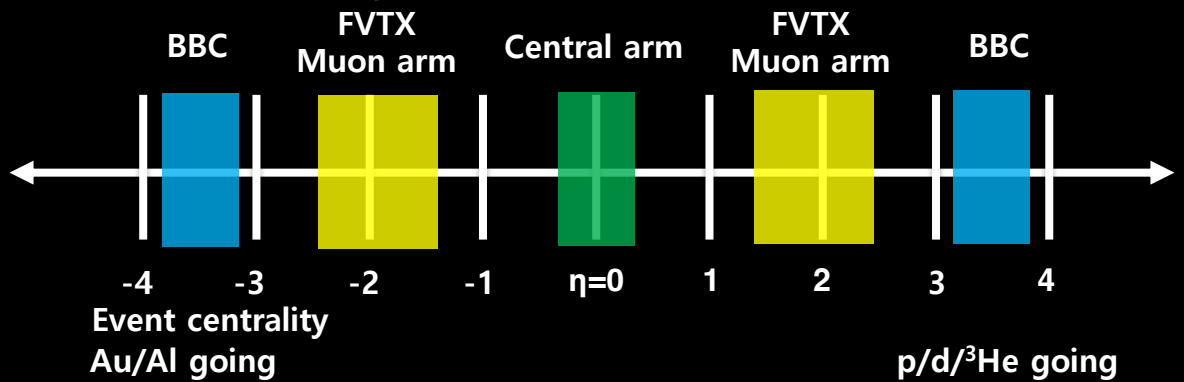
^{3}He+Au

Target size

p+Al

200 GeV



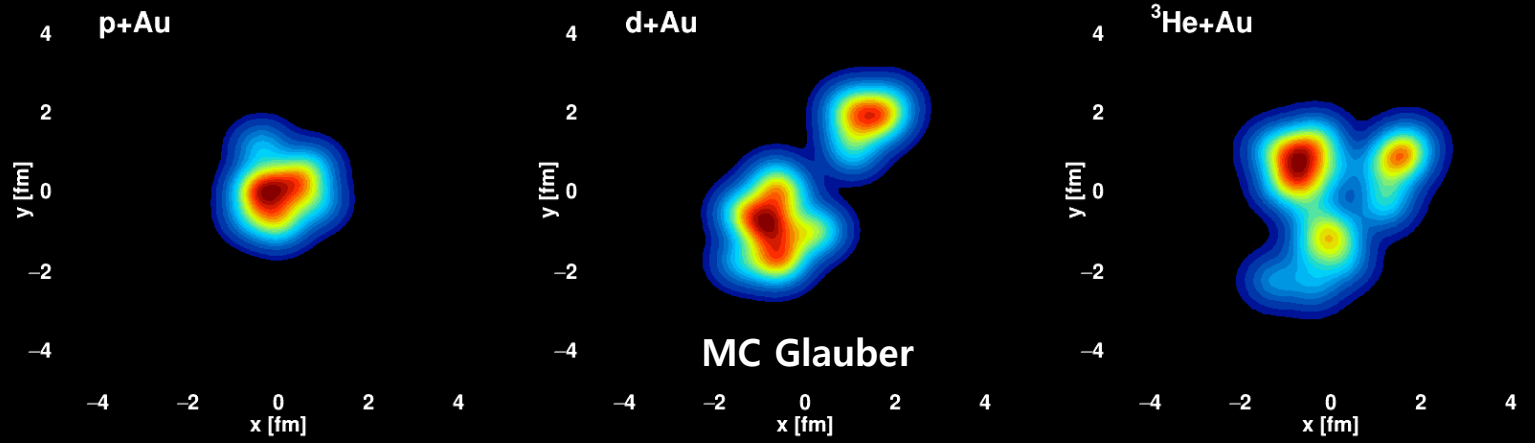


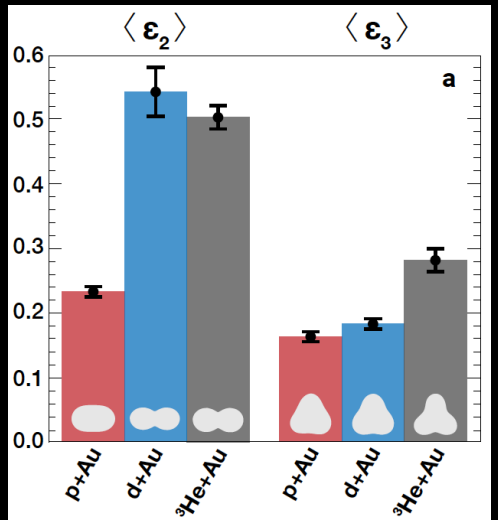
Beam energy

d+Au

200 GeV
62.4 GeV
39 GeV
19.6 GeV

Geometry engineering





Nature Physics 15, 214 (2019)

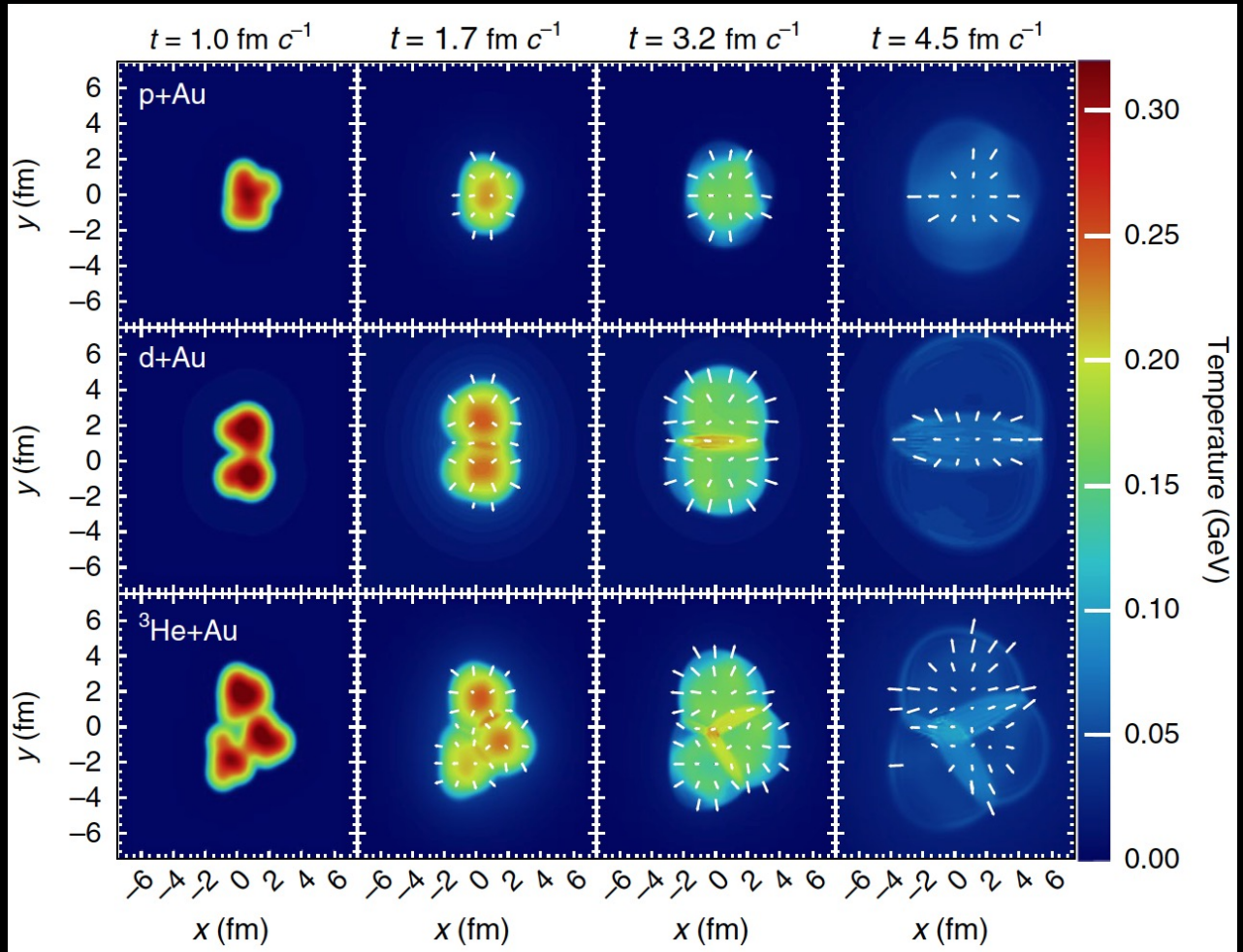
Smaller $\langle\varepsilon_2\rangle$ in p+Au
Larger $\langle\varepsilon_3\rangle$ in ^{3}He+Au

Various initial conditions

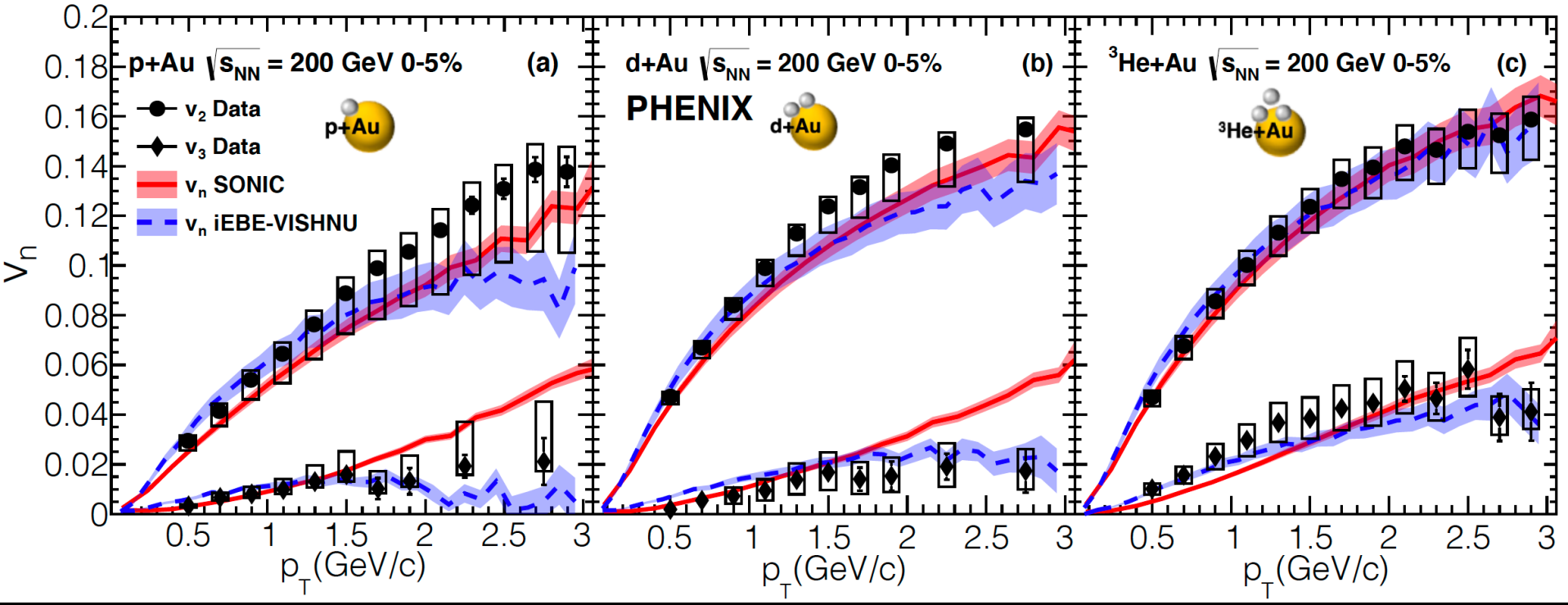
Collision system	Nucl. without NBD fluc.	Nucl. with NBD fluc.	Quarks with NBD fluc.	IP-G with nucl.	IP-G with quarks
			$\langle\varepsilon_2\rangle$		
p+Au	0.23	0.32	0.38	0.10	0.50
d+Au	0.54	0.48	0.51	0.58	0.73
^{3}He +Au	0.50	0.50	0.52	0.55	0.64
			$\langle\varepsilon_3\rangle$		
p+Au	0.16	0.24	0.30	0.09	0.32
d+Au	0.18	0.28	0.31	0.28	0.40
^{3}He +Au	0.28	0.32	0.35	0.34	0.46

PRC 105, 024906 (2022)

Geometry engineering

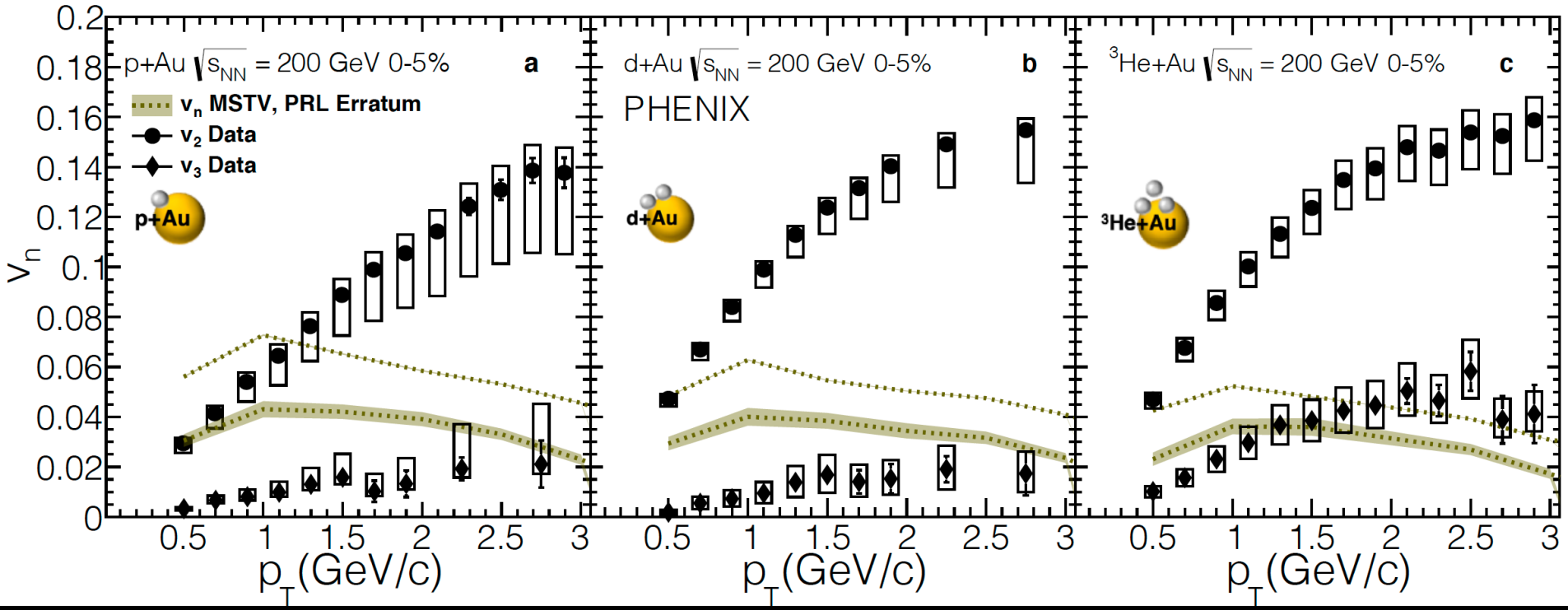


Nature Physics 15, 214 (2019)



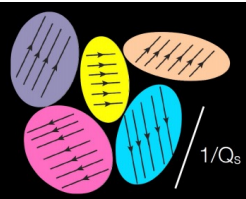
Nature Physics 15, 214 (2019)
PRL 113, 112301 (2014)
PRC 95, 014906 (2017)

Smaller v_2 in p+Au and larger v_3 in ^{3}He+Au
➔ Consistent with hydrodynamic models

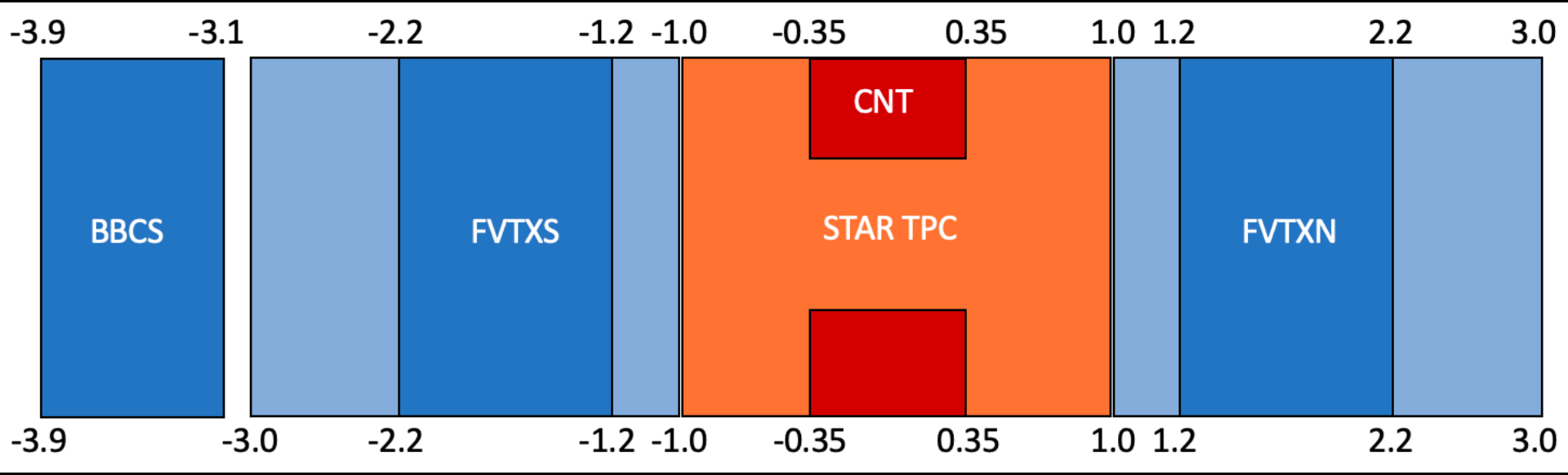


Nature Physics 15, 214 (2019)
PRL 123, 039901 (Erratum) (2019)

Initial-state correlation model fails to describe the data



Detector acceptance



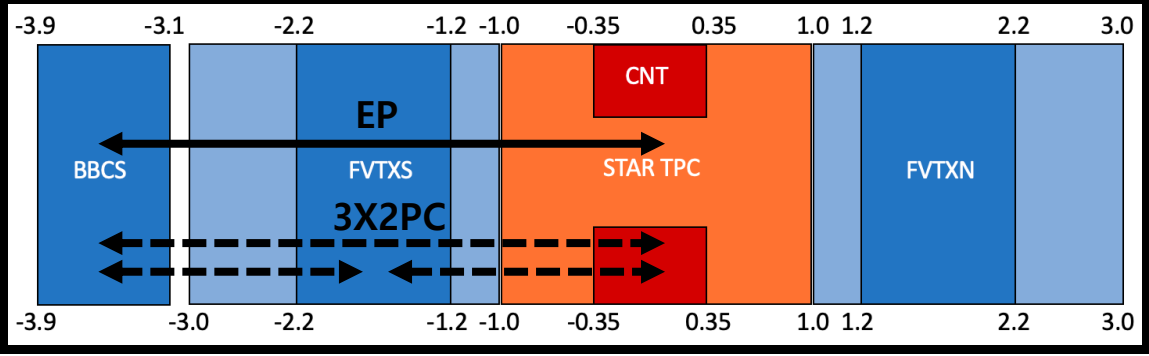
Two-particle correlation
w/ non-flow subtraction

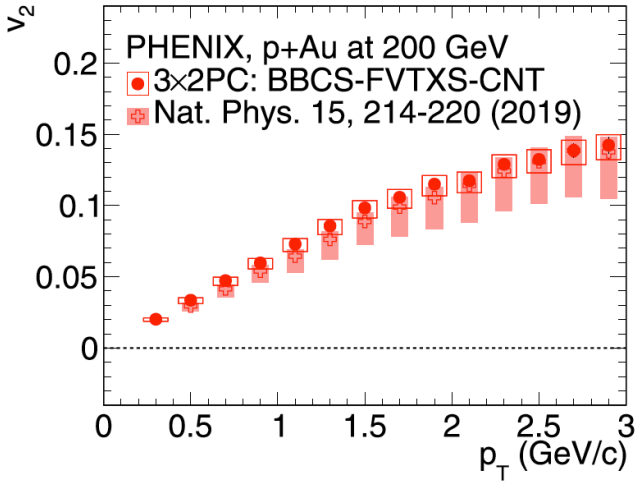
Event plane

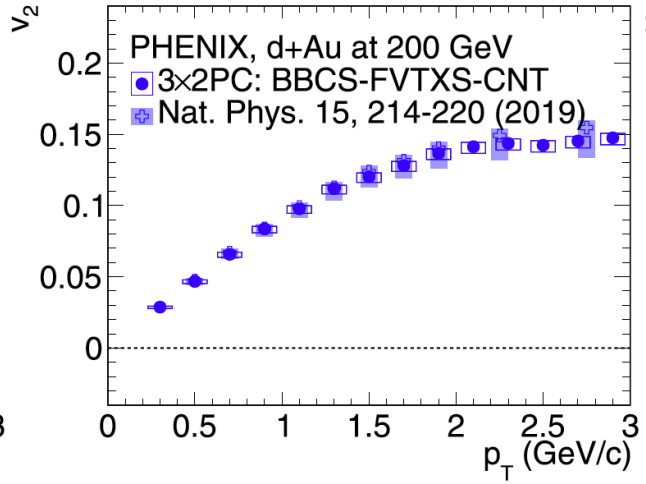
Three combinations of two-particle correlation

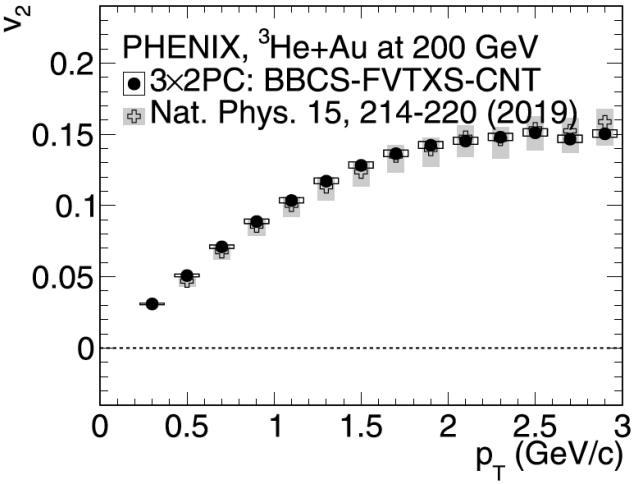
$$c_n^{AB} = \langle \cos(n(\phi_A - \phi_B)) \rangle = \langle v_n^A v_n^B \rangle$$
$$c_n^{AC} = \langle \cos(n(\phi_A - \phi_C)) \rangle = \langle v_n^A v_n^C \rangle$$
$$c_n^{BC} = \langle \cos(n(\phi_B - \phi_C)) \rangle = \langle v_n^B v_n^C \rangle$$
$$v_n^C(p_T) = \sqrt{\frac{c_n^{AC}(p_T) c_n^{BC}(p_T)}{c_n^{AB}}}$$

Flow with 2PC





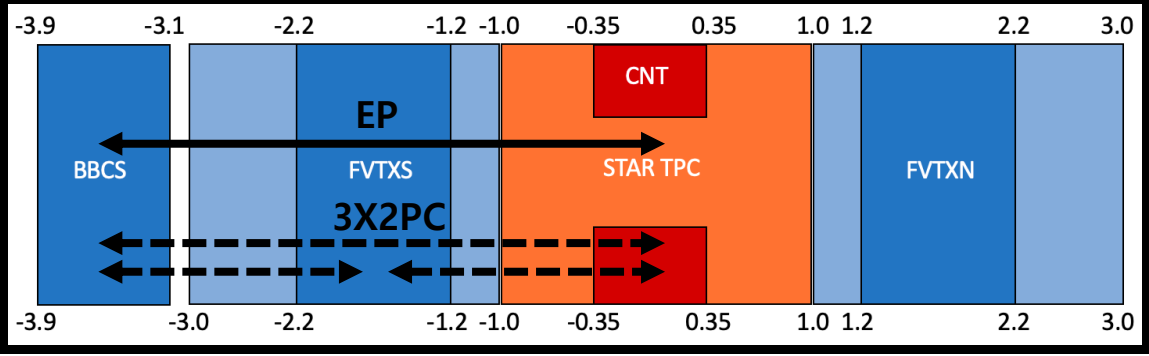


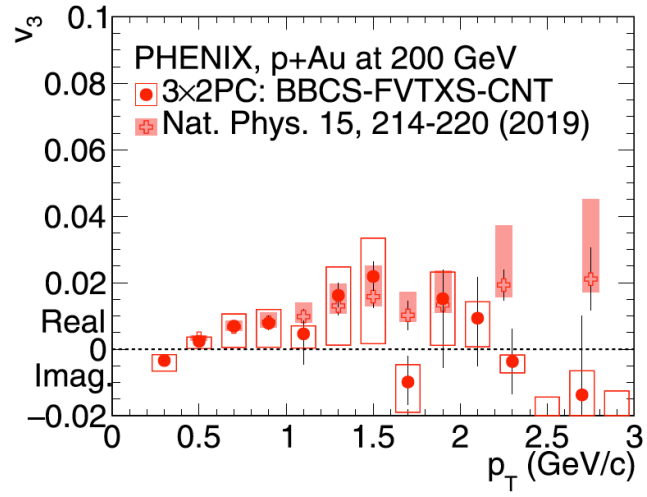


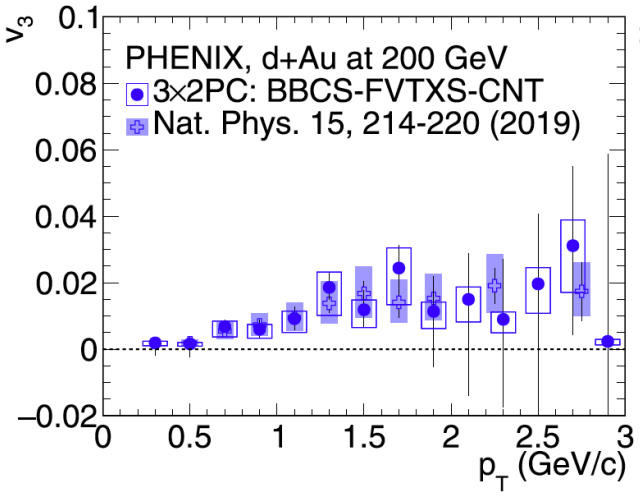
PRC 105, 024901 (2022)

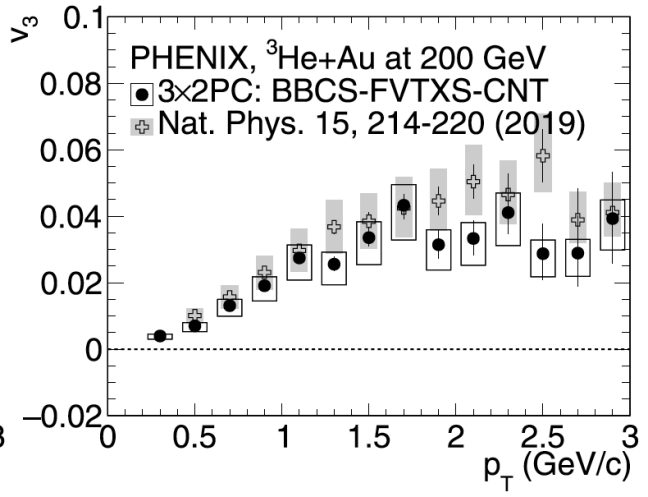
Consistent v_2 with two methods

Flow with 2PC





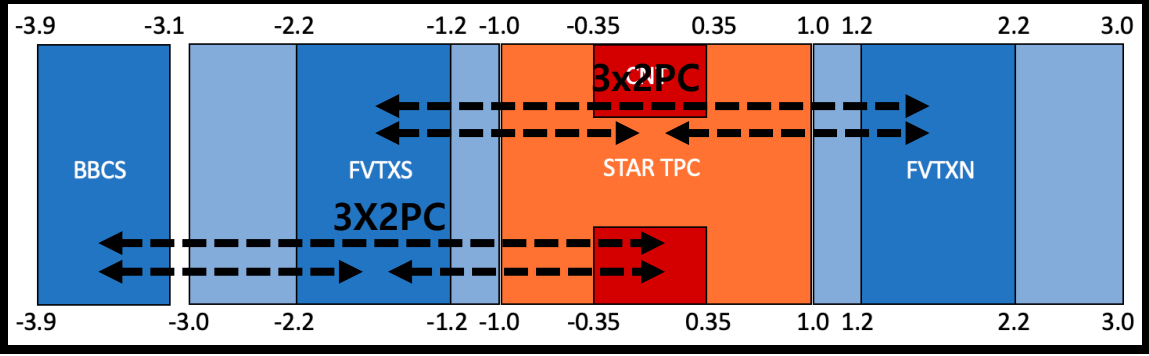


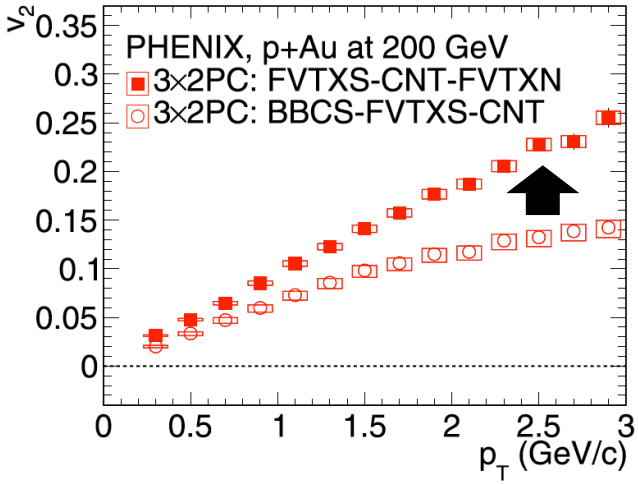


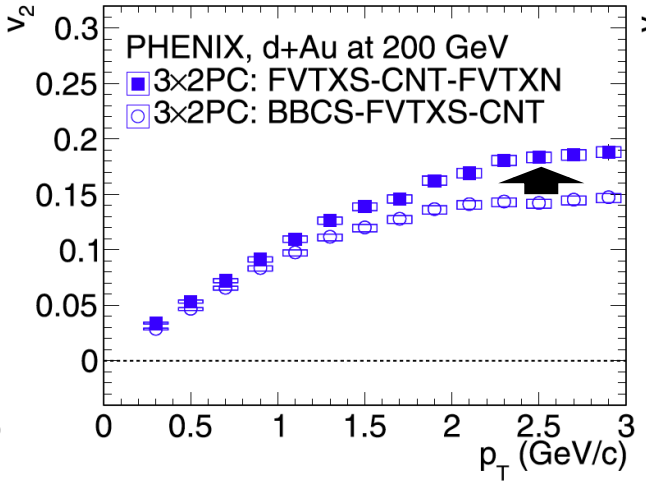
PRC 105, 024901 (2022)

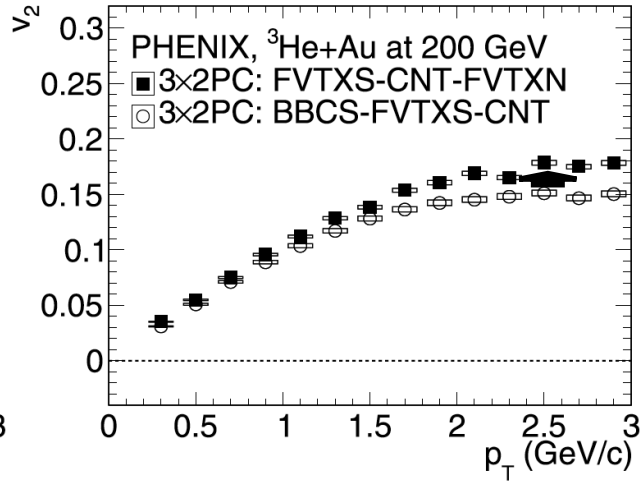
Consistent v_2 and v_3 with two methods

Flow with 2PC





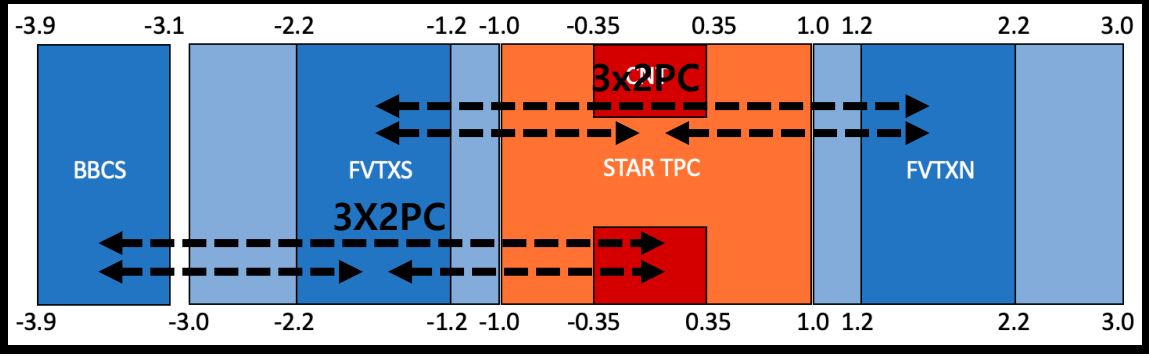


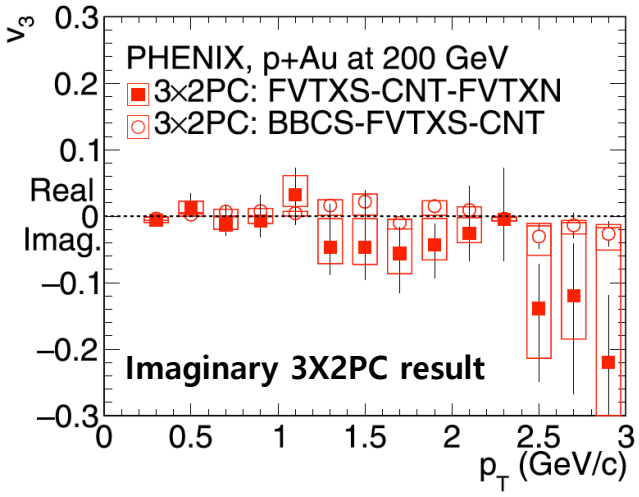


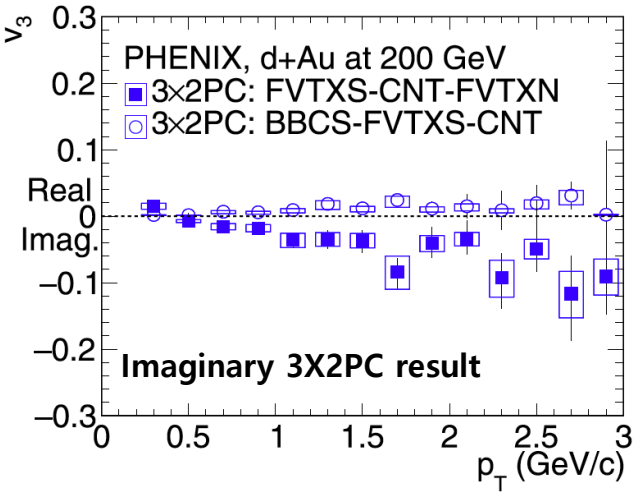
PRC 105, 024901 (2022)

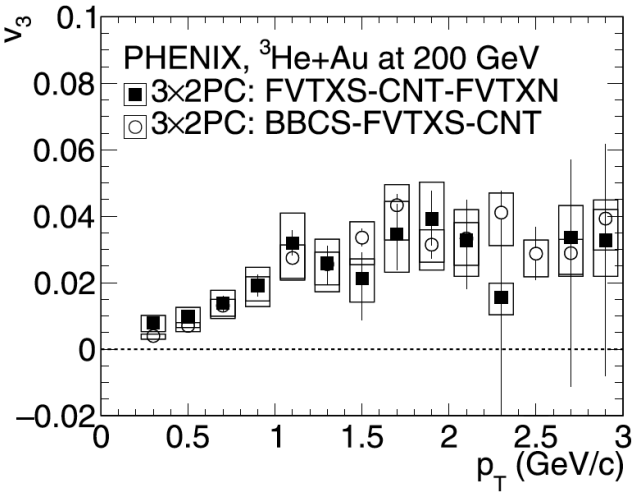
Consistent v_2 when using similar η coverage
Stronger non-flow in smaller η gap

Flow with 2PC





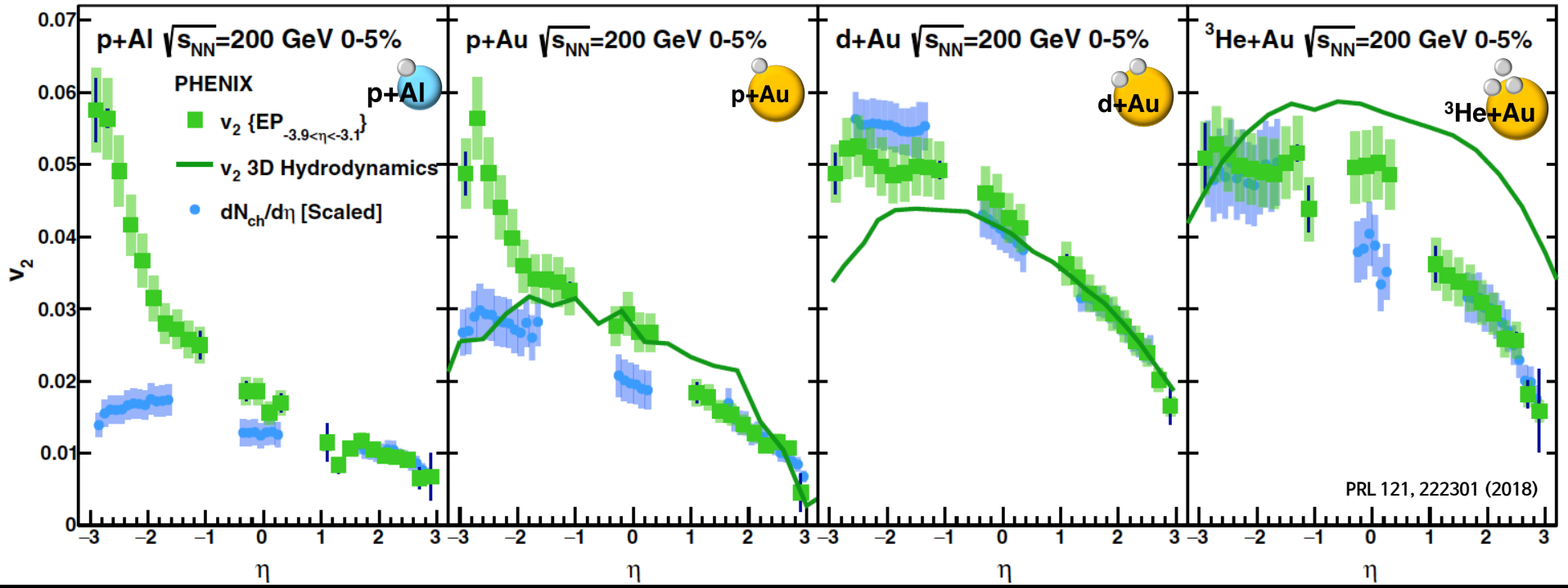


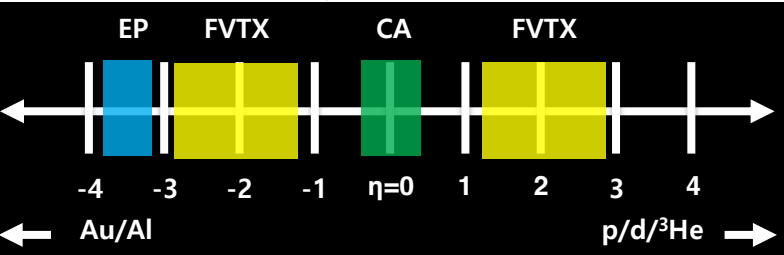


PRC 105, 024901 (2022)

Can not calculate v_3 in p+Au and d+Au due to negative coefficient c_3 between CNT-FVTXN

Collectivity in η

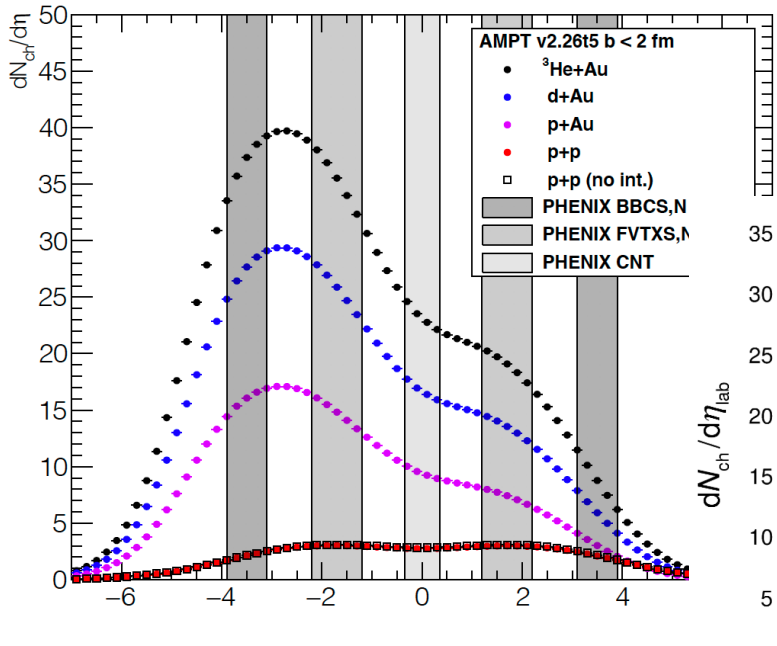


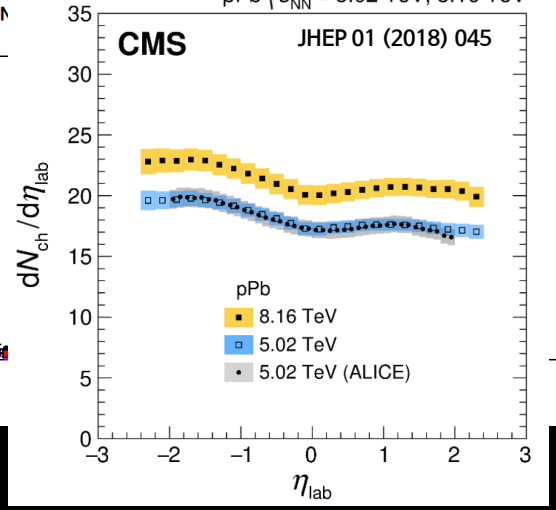


$v_2(\eta)$ in d+Au and ^{3}He+Au scales with $dN_{ch}/d\eta$

Sharp sudden rise in v_2 at backward in p+Al and p+Au likely from non-flow

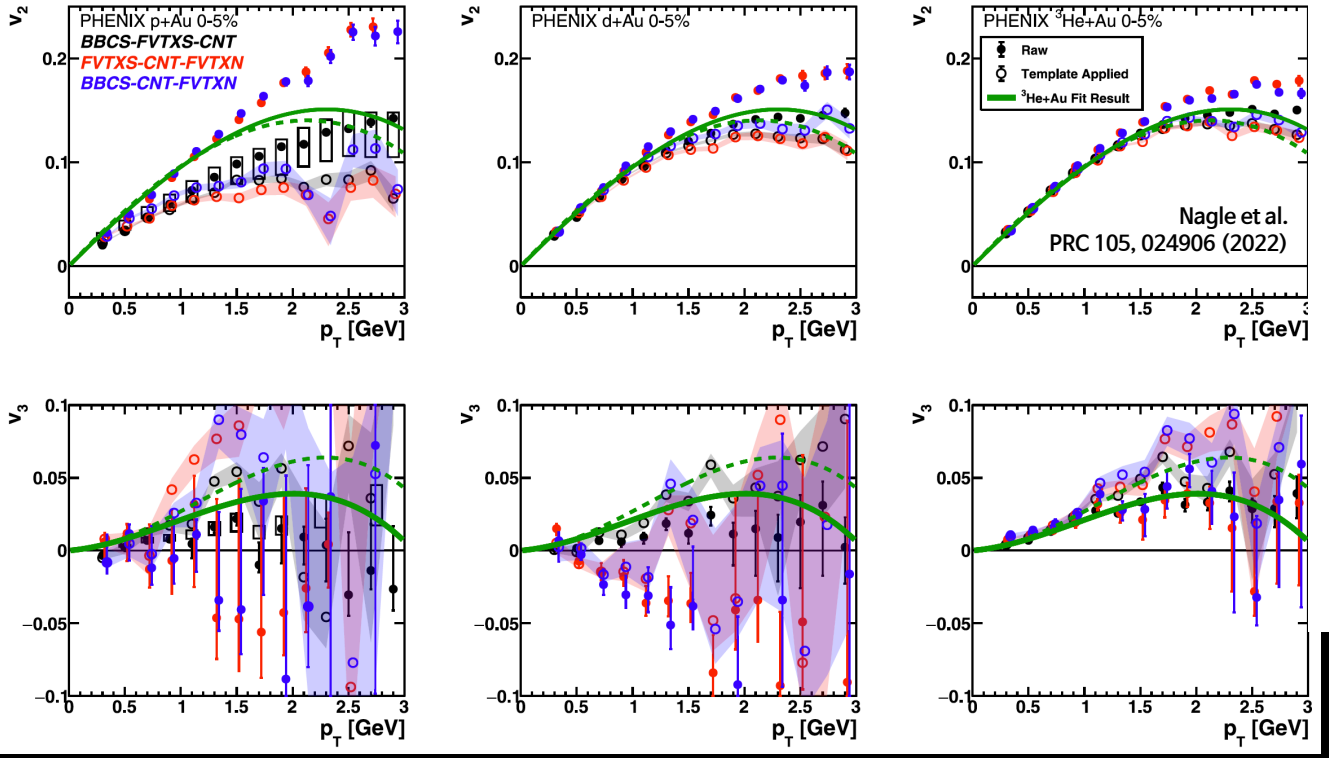
Longitudinal decorrelation? Pre-flow?

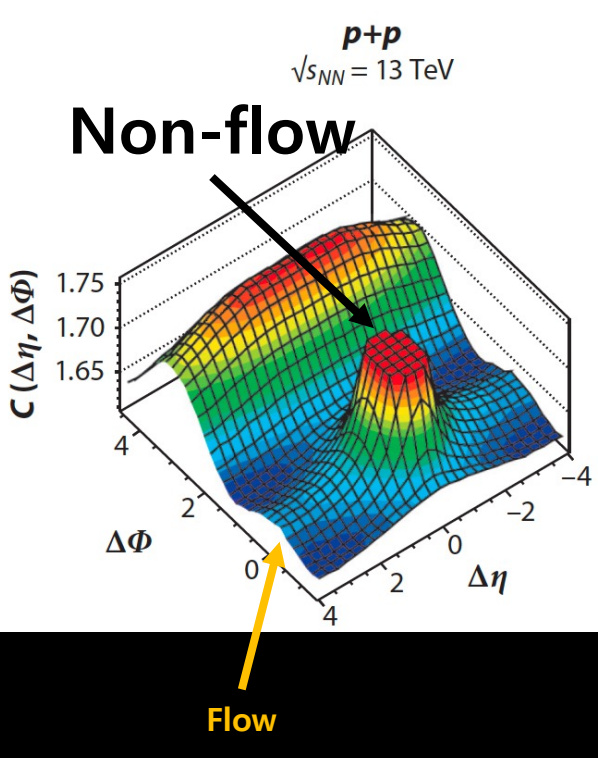




Significantly weaker translation of v_3 than v_2 in the lower multiplicity case

Non-flow subtraction

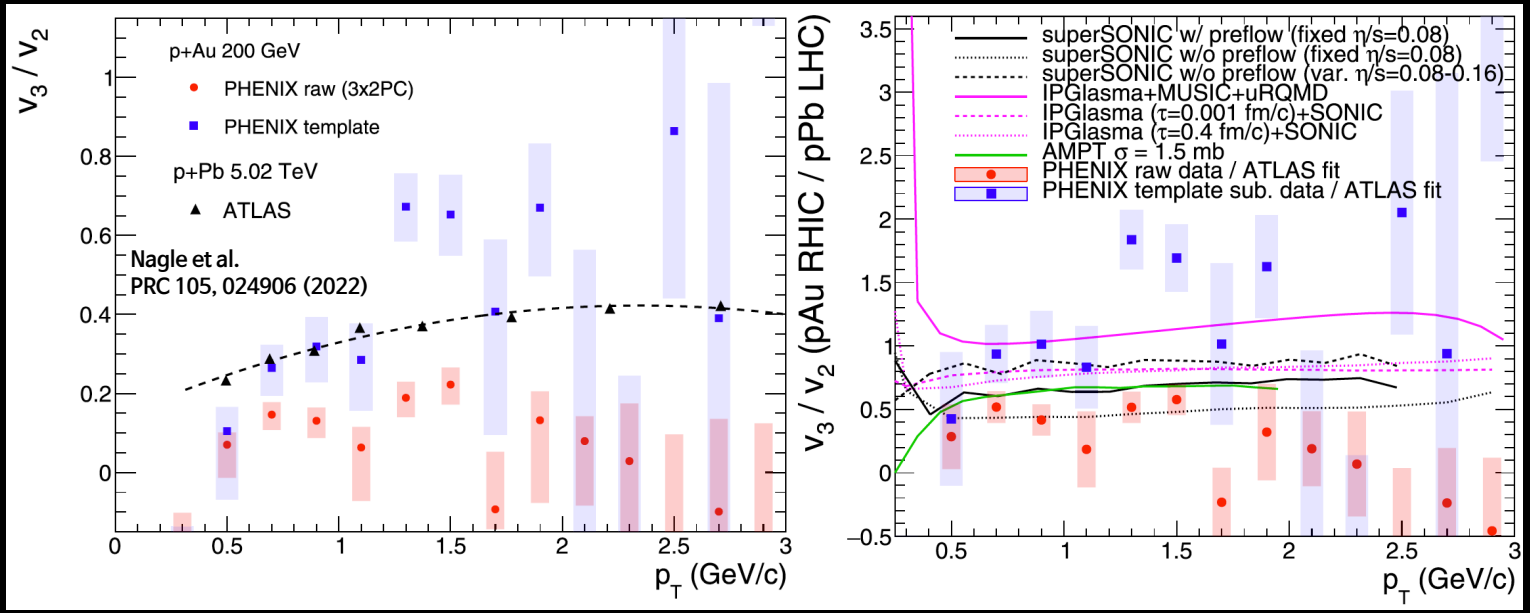




Unstable non-flow correction depending on systems and kinematic regions

Non-flow correction should be done carefully

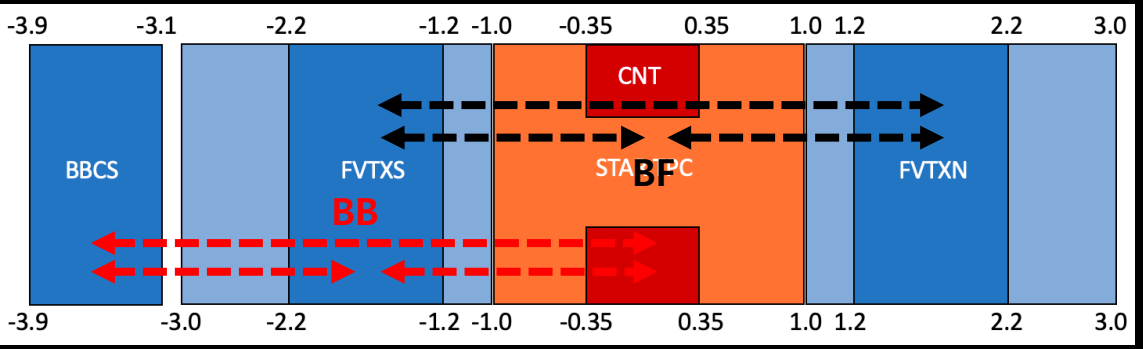
Comparison RHIC and LHC

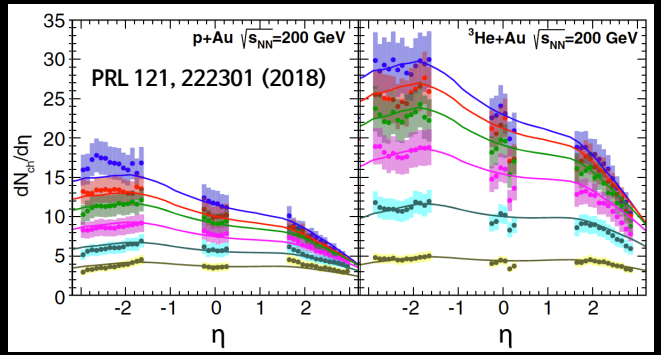


Most of theory calculations show higher v_3/v_2 at the LHC

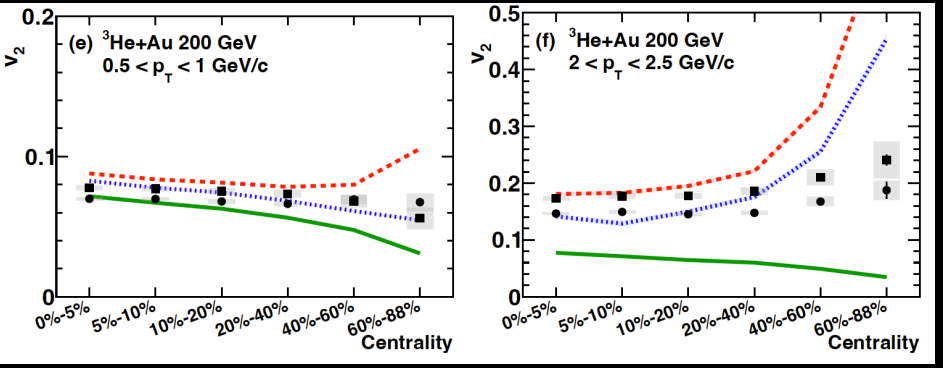
Non-flow subtracted results show higher v_3/v_2 at RHIC

Multiplicity dependence

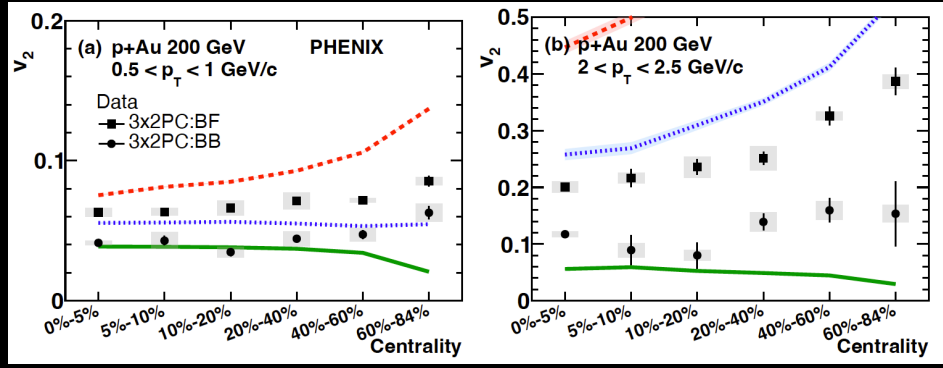




^{3}He+Au



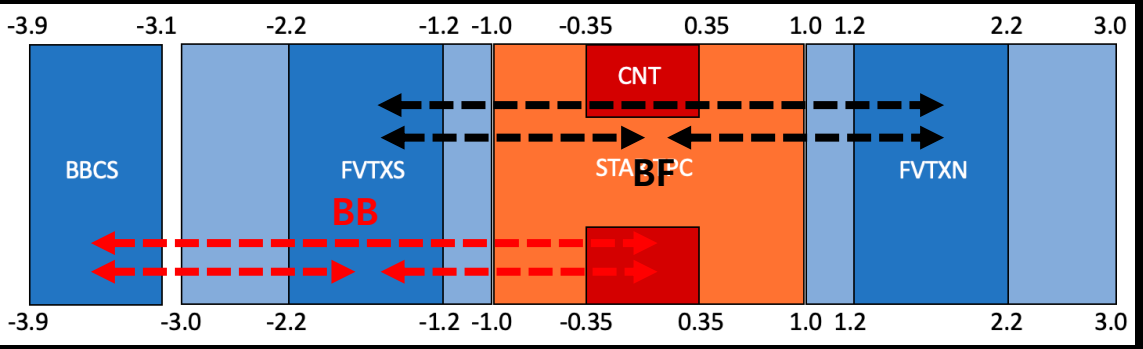
p+Au

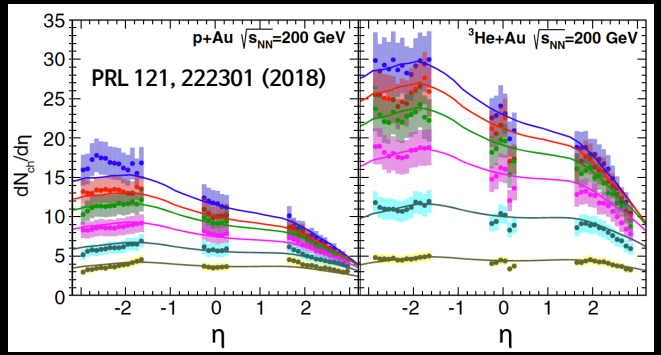


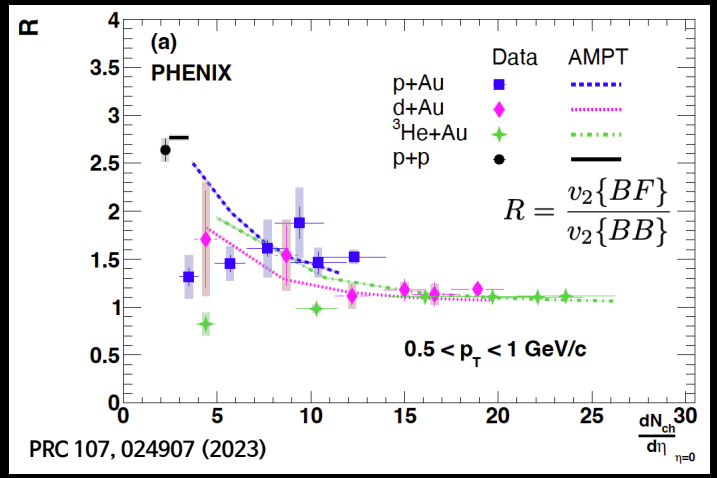
PRC 107, 024907 (2023)

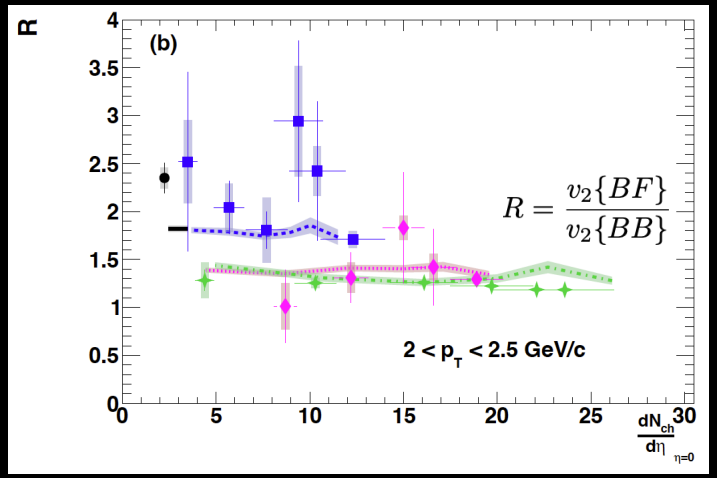
Stronger kinematic dependence in lower multiplicity and higher p_T

Multiplicity dependence







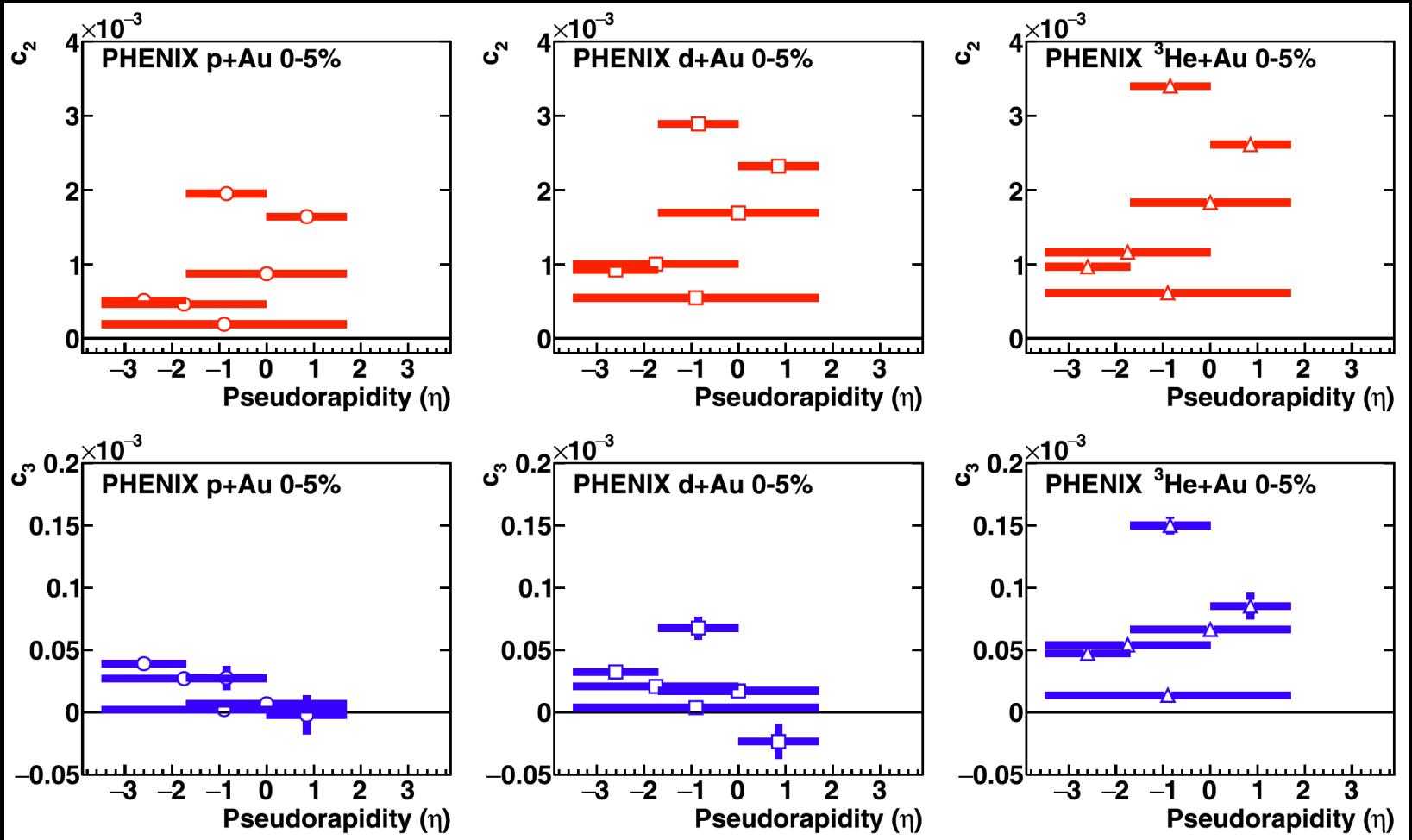


AMPT qualitatively describes the kinematic dependence

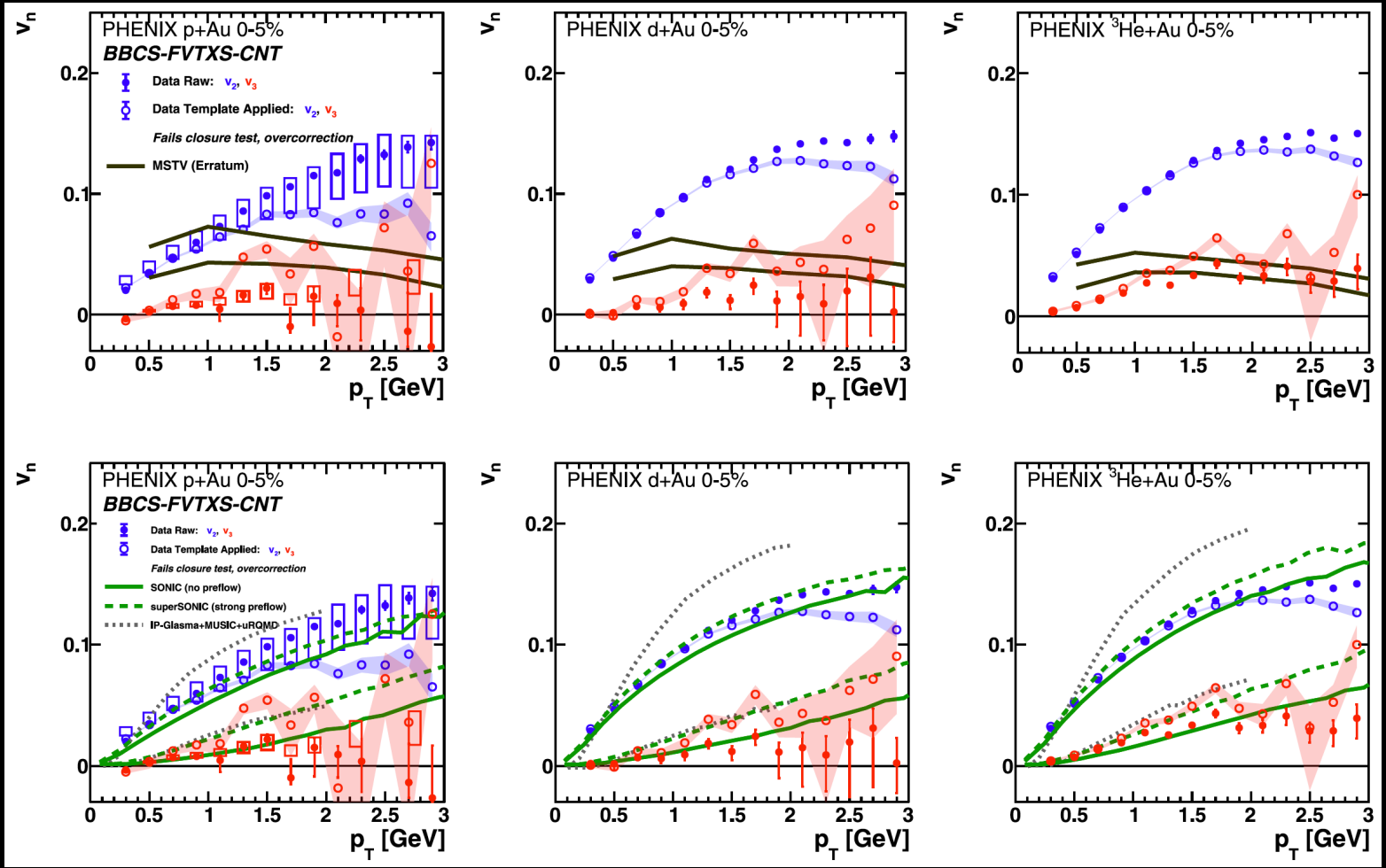
- **PHENIX has performed extensive studies on collectivity in small systems**
  - Comparison of two methods in the same kinematic region:
    Obtained consistent v_2 and v_3 with the EP method and the 3X2PC method
  - In the other kinematic region with a smaller $\Delta\eta$ gap:
    Could not extract v_3 due to negative Fourier coefficients
    Stronger kinematic dependence in lower multiplicity and higher p_T

- **In smaller multiplicity, the flow coefficients are very sensitive to:**
  non-flow effect, fluctuation, decorrelation

BACKUP


c_2
$\times 10^{-3}$
PHENIX p+Au 0-5%
PHENIX d+Au 0-5%
PHENIX ^{3}He+Au 0-5%
c_3
Pseudorapidity (η)

Model comparison



Non-flow correction in models